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Tightly Bending Loss Measurement for 1.3 μm and 1.55 μm Broadband Wavelength Division Multiplexing Fiber Sensor Systems

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ABSTRACT

A tightly bending loss technique is developed for application in biomedical WDM fiber sensors. In this paper, we present the measurement and comparison of bending sensor in 1.3 μm and 1.55 μm wavelength region, respectively. A two - wavelength measurement setup is built for bending loss testing. Various wrapping method and turns are invested for studying the bending loss for broadband biomedical sensing system. We found that as the bending loss increases, the oblique angle of wrapping become large. These research results is helpful for multi-channel multi-array fiber optic biomedical sensor systems.

Keywords : Biomedical sensor, Fiber Sensor, Bending Loss, Wavelength Division Multiplexing

1. INTRODUCTION

Biomedical fiber-optical sensors attract a lot of attentions in last ten years[1-2]. Bending fiber-optic sensors are simple and cost effective. The fiber-optic bending sensors can be applied to measure many physical quantities, such as voltage, strain, temperature, pressure, etc [3-11]. With the wavelength division multiplexing techniques intensively grew up [12], multichannel high-speed WDM distributed fiber-optic bending sensor become an important issue[13-14]. Such WDM fiber bending sensors can be applied in biomedical sensor systems.

In this paper, the bending fiber sensor we developed are using the Walsin- Fujikura single mode fiber (Spec No. : NWF-98F101, SM.10 / 125.04.UV)[15] which is commonly used in Taiwan. Three wrapping schemes: normal wrapping, overlap

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wrapping and cross wrapping are considered. The tightly bending losses are measured with the three wrapping schemes with bending radius 1 mm to 25 mm. The bending losses are different in 1.3 μm and 1.5 μm with various wrapping schemes and bending radii. We also analyze the bending loss with various wrapping turns. In broadband WDM fiber biomedical bending sensor system, it is important to determinate the wavelength responses in different wavelength channels. The experimental results can be used for clarifying the relationship between the maximum number of bending loss sensor and the operation wavelength band.

Owing to bending and unsuitable wrapping structure will induce tension in process of the fiber manufacture and construction, the optical transmission signal will experience the extra radiation losses and be attenuated. Although several bending loss measurement standard have been developed[16,17], only a few papers discuss about wrapping in various structure, turns and wavelength have been reported [18-19]. This work is important for future achieving wide-band WDM biomedical fiber sensors systems, including manufacturing, constructing and cabling process. In the following, we will concentrate on bending loss mechanism, and the bending loss characteristics in various wavelength windows. The following sections show the experimental setup and results.

2.DESCRIPTION OF EXPERIMENTAL ARRANGEMENT

The schematic diagram of the experimental apparatus consist of two laser sources operating at 1.3μm and 1.55μm wavelength, the fiber is wrapped around a mandrel with various diameters R, the end is a power meter for reading the power losses, as shown in Fig .1. The schematic diagram of the wrapping style is considered three schemes: normal wrapping, cross wrapping and overlap wrapping as shown in Fig .2.

3.EXPERIMENTAL RESULTS

3.1 The relation of bending losses v. s. bending radius

Some Walsin-Fujikura single mode fibers (SM.10 /12504UV) are used for the following experiments. Their mode field diameter is 9.3 ± 0.5 μm at 1310 nm, cladding diameter is 125 ± 1.0 μm and outer coating diameter is 245 ± 10 μm .Their typical refractive index difference value is 0.36 % , and intrinsic attenuation value is 0.35 dB / km at 1.3 μm wavelength and 0.22 dB / km at 1.55 μm wavelength. The bending losses versus the bending radii are shown in Fig .3. The bending losses with radii from 1mm to 10 mm are measured at 1.3 μm and 1.55 μm wavelength windows. The bending losses are larger at 1.55 μm than at 1.3 μm wavelength. When the fiber is bent smaller than radius of 10 mm, the bending loss will increase from 0 dB to 70 dB rapidly at 1.55 μm and bending loss will increase from 0.5 dB to 2.5 dB at 1.3 μm. Obviously, the smaller bending radius will induce the bigger bending loss. Especially, the bending loss is obviously become higher with radius $R < 3$ mm at 1.55 μm.

3.2 The relation of bending loss v. s. wrapping scheme

The fiber is wrapped around a mandrel of 25 mm diameter in this subsection. The power losses versus 1 to 20 turns with three wrapping schemes: normal, overlap and cross wrapping at 1.3 μm are shown in Fig .4. Obviously, the bending loss is a function of loop turns with various wrapping. The bending loss belongs to the cross wrapping comparing with the overlap wrapping and the normal wrapping schemes show large variation with respect to wrapping turns. Therefore, how the fiber was wrapped is important for fiber bending sensor design. The most sensitive scheme is cross wrapping bending fiber sensor. The same phenomenon happen at 1.55 μm wavelength, but losses is much higher. As shown in Fig .5, we find that the bending loss sensitivity of the wrapping scheme at 1.55μm wavelength is higher than at 1.3 μm wavelength, so the sensitive wavelength band is 1.55 μm for WDM optical bending fiber biomedical sensor system.

3.3 The relation of bending loss v.s. wrapping oblique angle

The fiber was wrapped with oblique angle θ from 0° to 60° experimentally . As shown in Fig .6 and Fig .7, the bending loss is a function of oblique angle, the fitting bending loss functions can be written as :

$$L_{1.3\mu m}(\theta) = 0.0064\theta^2 - 0.2144\theta + 0.6467, \qquad (1)$$

$$L_{1.55\mu m}(\theta) = 0.0218\theta^2 - 0.4354\theta + 1.1514, \qquad (2)$$

For comparison, the experimental and theoretical curves shown in Fig .6 and Fig .7 show the difference between the 1.3 μm and 1.55 μm. The bigger the wrapping oblique angle, the bigger the losses in both wavelength. The bending losses are still greater at 1.55 μm than at 1.3 μm wavelength. Especially, the laser operating at 1.55 μm wavelength for WDM optical fiber biomedical sensor system show promising sensitivity with respect to the oblique angle. The oblique angle of wrapping is demonstrate as an important parameter for WDM optical bending fiber biomedical sensor system in the first time.

3.4 The relation of bending loss v. s. wrapping interval

The fiber was wrapped 5 turns with interval from 1 mm to 5 mm. In Fig .8 and Fig .9, the bending loss is a function of wrapping interval, the fitting functions can be represented as:

$$L_{1.3\mu m}(D) = -0.0046D^2 - 0.219D + 0.3907, \qquad (3)$$

$$L_{1.55\mu m}(D) = -0.0568D^2 - 0.1766D + 7.2921, \qquad (4)$$

Comparing the experimental and theoretical curves shown in Fig.8 and Fig.9, the theoretical fitting curve is well matched the experimental data. The bigger the wrapping interval, the smaller the losses we found. The bending loss sensitivity of wrapping interval at 1.55 μm wavelength is still higher at 1.55 μm than at 1.3 μm wavelength. So the better light source is 1.55 μm wavelength for WDM optical fiber sensor system. The interval of wrapping is also an important parameter considered for WDM fiber biomedical sensor network.

4.CONCLUSION

In summary, before achieving a broadband WDM fiber-optical bending biomedical sensor networks, we measured the

bending losses in 1.3 μm and 1.5 μm band with various bending radius, wrapping schemes, and turns. Based on those experimental results, we built up some simple theoretical models for describing the design rules. In the future, the models can be applied to develop a WDM fiber biomedical sensor system as shown in Fig.10. This work is very helpful for future broadband WDM fiber biomedical sensor network. Because the transceiver in 1.3 μm and 1.55 μm band are cost effective for applying in fiber communication systems, we believe using 1.3 μm and 1.55 μm light for broadband WDM distribution fiber biomedical sensor systems is possible in the future.

5.ACKNOWLEDGE

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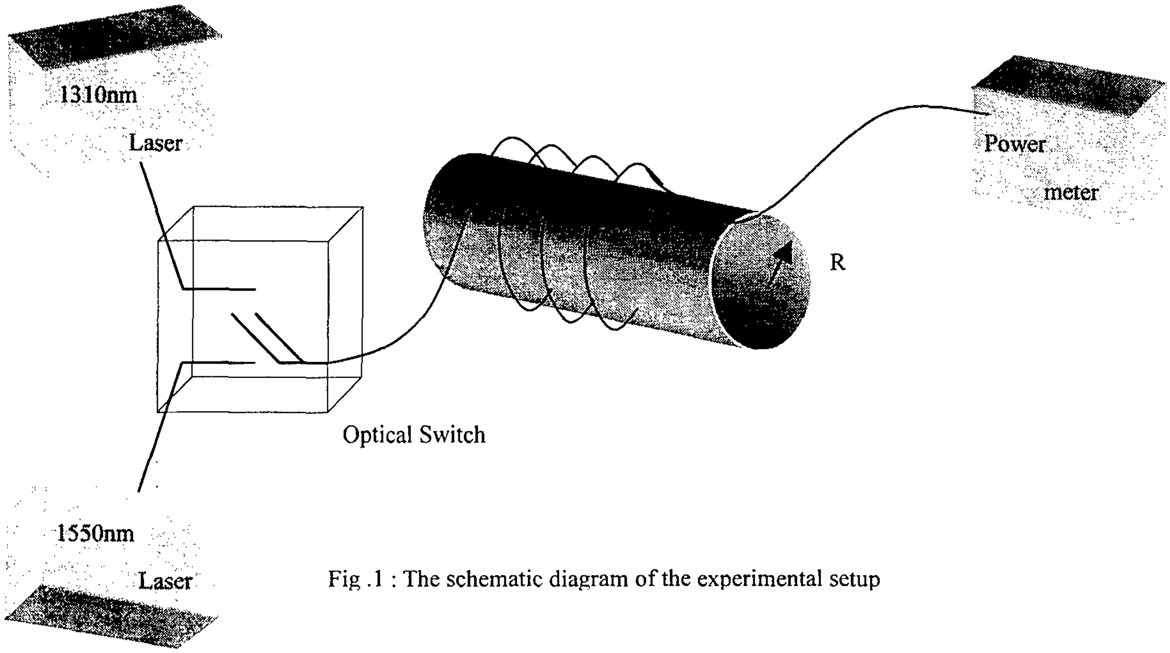
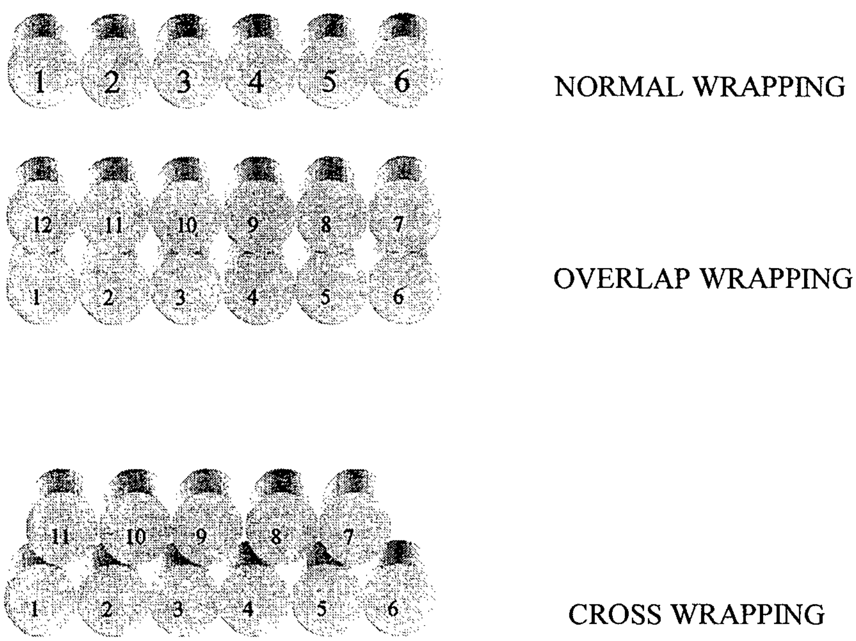


Fig .1 : The schematic diagram of the experimental setup



F i g .2 : The schematic diagram of various wrapping structure

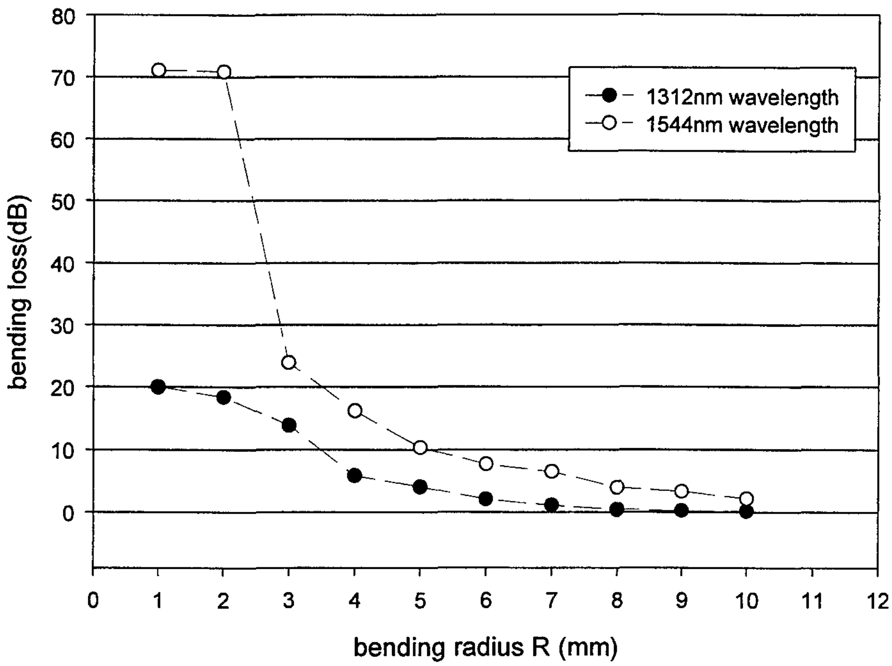


Fig . 3 : The bending loss v.s. bending radii

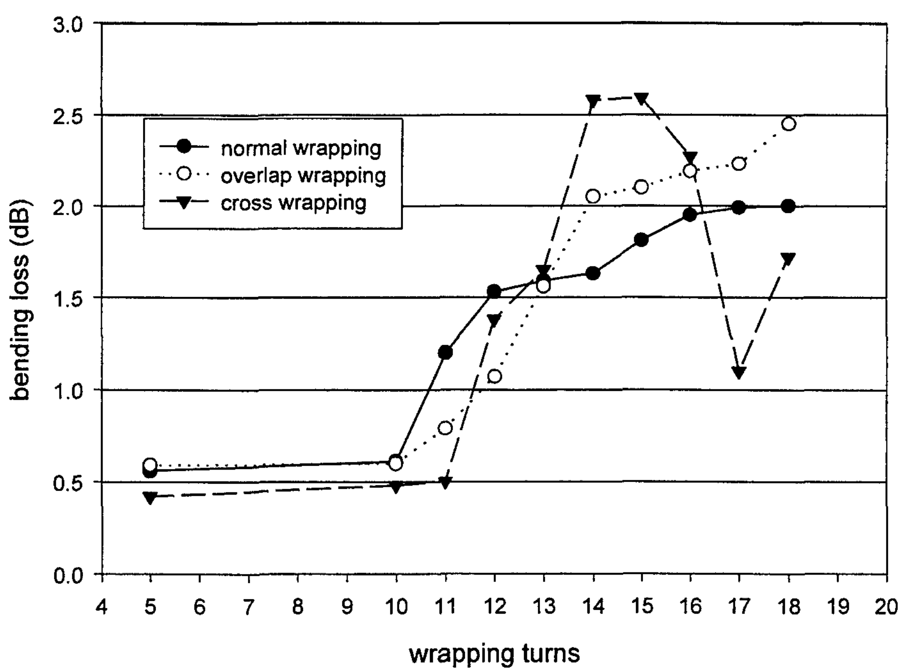


Fig . 4 : The bending loss v.s. wrappimg turns at 1312 nm

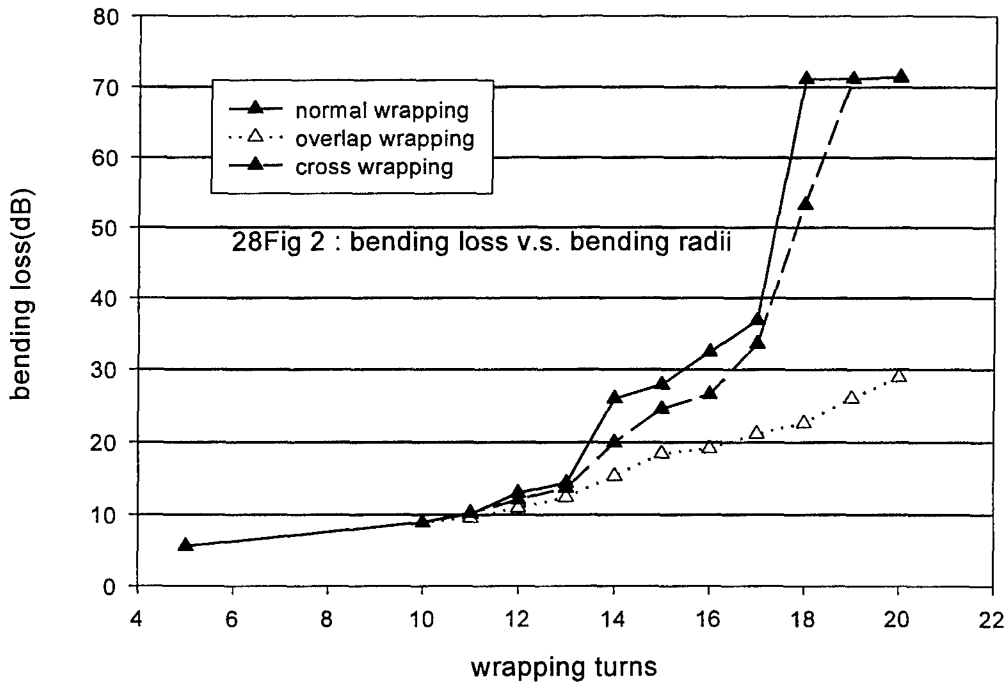


Fig . 5 : The bending loss v.s. wrapping turns at 1544nm

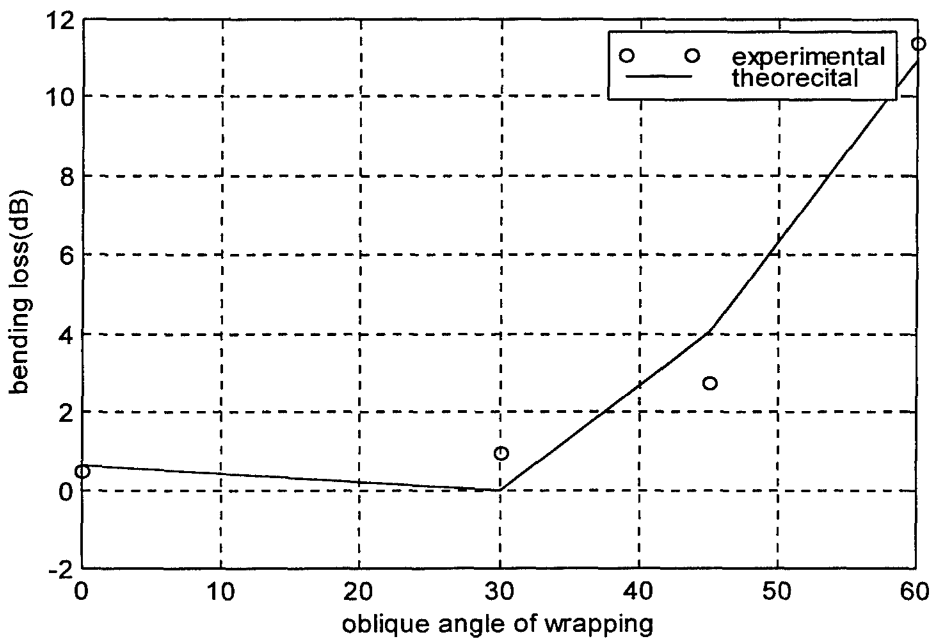


Fig .6 : The bending loss v.s. oblique angle of wrapping at 1.3 μm wavelength

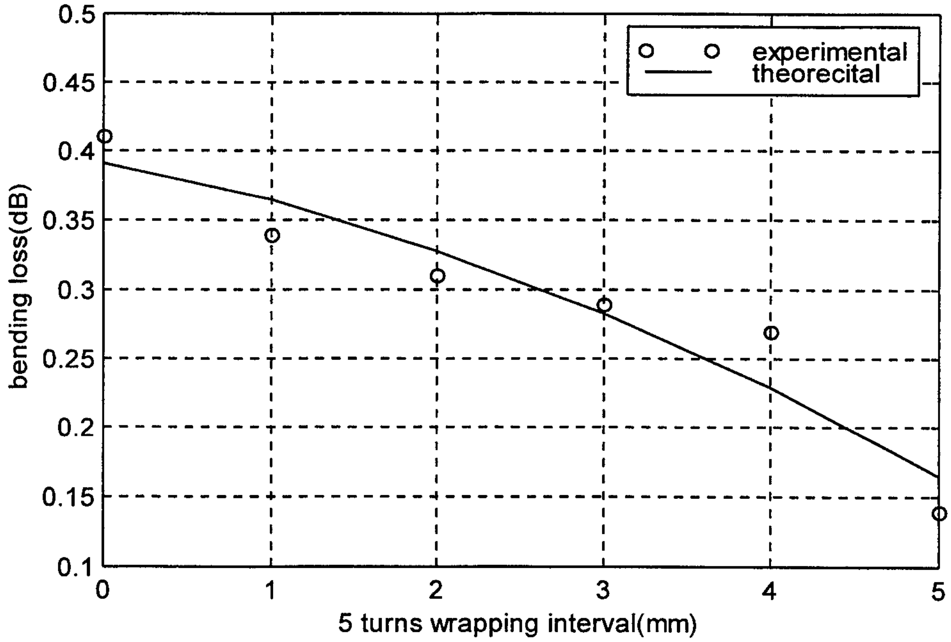


Fig. 7 The bending loss v. s oblique angle of wrapping at 1.55μm wavelength

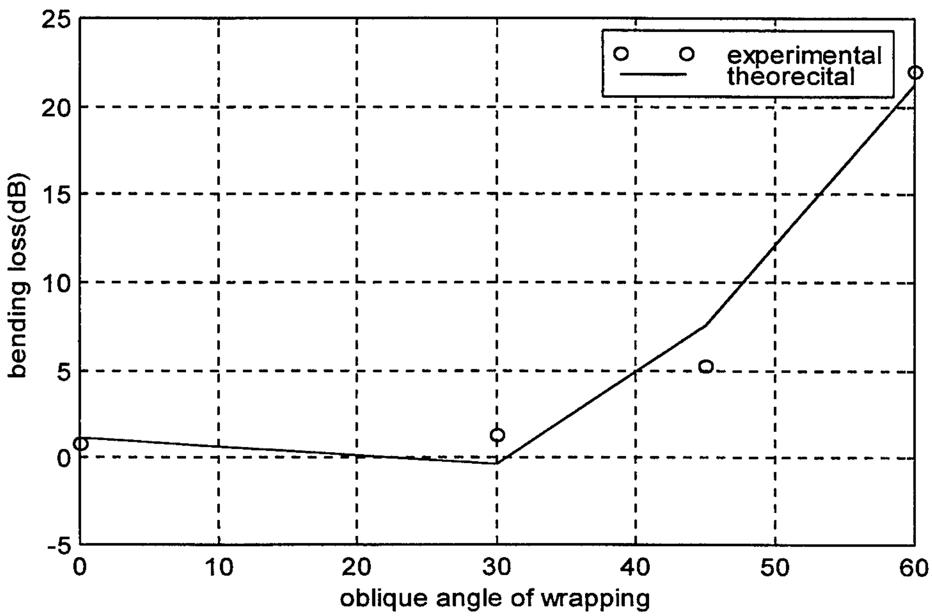


Fig .8: The bending loss v.s. wrapping interval at 1.3 μm wavelength

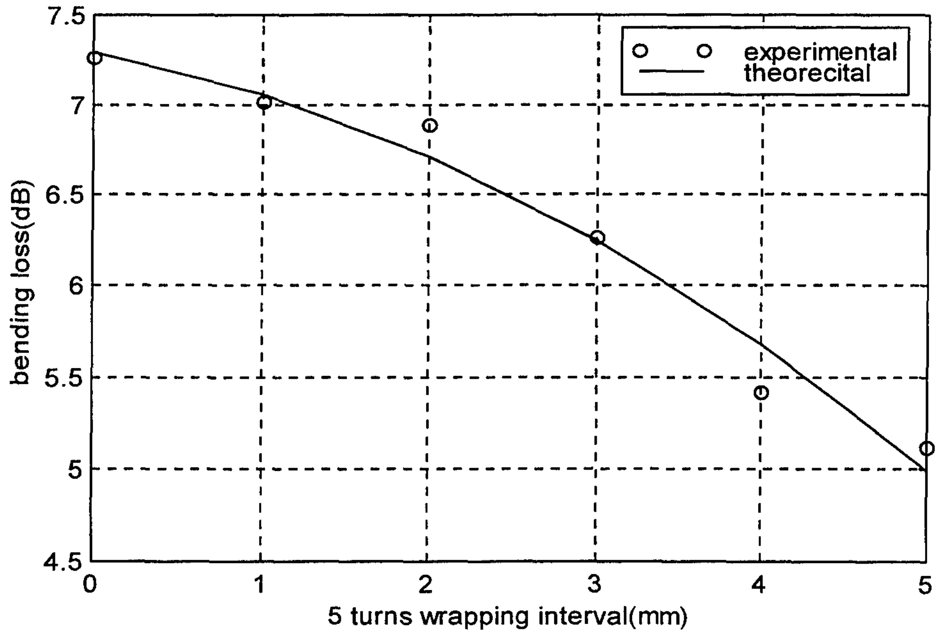


Fig .9 : The bending loss v.s. wrapping interval at 1.55 μm wavelength

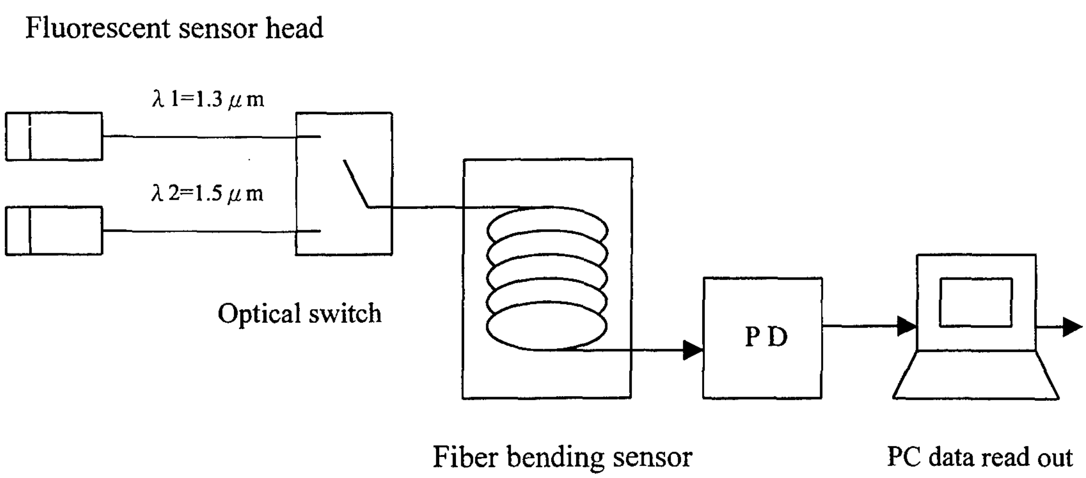


Fig.10 : Schematic diagram of a WDM bending sensor